Boosting Efficiency of Split Marine Container Terminals by Innovative Technology

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Abstract-- **The growth of container shipping is putting enormous pressure on seaports, hinterland transport networks and inland infrastructure. With vessels becoming bigger and bigger, storage in container ports is becoming more and more land consuming, driving container ports to their spatial limits. Because of these factors, a multi-year research project was launched in the U.S. It resulted in a remarkable proposal to split container ports into an "Efficient Marine Terminal" part ashore and an "Intermodal Interface Center" inland, both connected by a dedicated railway line.**

As the American research project focussed on saving land on shore, there remained some potential to improve container handling productivity in both, the "Efficient Marine Terminal" and the "Intermodal Interface Centre".

Driven by German Railways DB's desire to concentrate container flows by introducing a hub and spoke production system, Noell Crane Systems developed a container handling technology that allows for the transhipment of containers between freight trains instead of shunting wagons in 1995. Thus reducing the dwell time of the wagons by an amazing 75%. Featuring a highly efficient box mover for the sorting of containers prior to loading them on to the trains, this MegaHub, as it is called, is exactly the technology required for the "Intermodal Interface Center."

As for the "Efficient Marine Terminal" Noell is proposing a technology featuring the allocation of rail-mounted gantry cranes spanning rail tracks used in conjunction with a box mover directly under the quay cranes. This enables the containers to be transhipped between vessel and freight trains without the need to start moving the quay cranes along the vessel for positioning purposes. The big advantage of this concept is that yard transfer vehicles are not required, saving a great deal of machinery and labour, which is not particularly cheap in the western part of the world.

With the container handling equipment proposed being of proven technology, there is the great opportunity now to realize a challenging logistical solution for high throughput marine container terminals in crowded locations.

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Index terms-- **Intermodal Transport, Container Terminals, Container Handling Technology, Agile Port System, Efficient Marine Terminal, Intermodal Interface Center, Mega Hub, Container Sorting Facility, Linear Motor-Based Transfer Technology**

I. INTRODUCTION

Container ports are break points in the intermodal transport chain. To absorb differences in time and quantity between ocean flows and inland flows, and often due to a lack of information as to the next step of the journey, containers have to be stored on shore. To avoid disastrous effects of the ocean peaks on landside public transport systems, as a rule, containers are stored as close as possible to the quay. This requires sufficient internal transport and stacking crane capacity to cope with the peak demands instead [1].

With average dwell-times per container of several days (e.g. 6 to 8 days in U.S. marine terminals [2], depending on the location of the port) and vessels becoming bigger and bigger, storage in container ports is demanding more and more space and driving ports to their spatial limits. As a result, there are endeavours to shift storage facilities from ocean harbours to inland facilities.

II. OUT-PLACING STORAGE FACILITIES FROM OCEAN HARBOURS – THE AGILE PORT SYSTEM

Some years ago a multi-year research project was launched by the U.S. Transportation Command (USTRANSCOM), the U.S. Maritime Administration (MARAD) and the Center for Commercial Deployment of Transport Technologies (CCDOT) resulting in a proposal (Agile Port System [2]) to split a container port into an "Efficient Marine Terminal" (EMT) ashore and an "Intermodal Interface Center" IIC) inland both connected by a dedicated railway line.

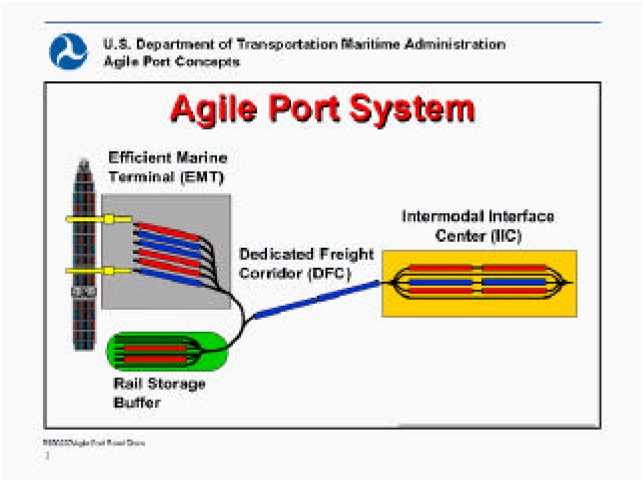

Fig. 1: The Agile Port System [2], [3] - Splitting marine container ports into two parts

The idea behind the Agile Port System (Figure 1):

- Handling as many containers as possible between vessels and trains without storing them in the EMT.
- Immediate transport of containers between EMT and IIC by train.
- Sorting of containers between trains according to their final destination (the IIC favourably being linked to several marine terminals [1] in order to increase service frequency.)
- Loading and unloading of trucks which serve the region nearby taking place inland at the IIC.

III. Adding Efficiency to Reduced Land Requirements – The "Efficient Marine Terminal"

Creating The "Efficient Marine Terminal" as proposed by the U.S. consortium operates like a conventional marine terminal, but features a rail interface instead of a conventional yard. Vessels are unloaded at the EMT and yard vehicles transport containers in much the same way as they are now, but the containers are then loaded directly onto trains in the yard. Some buffer storage would be provided in a separate area, but most of the containers would leave the terminal directly. The main idea behind the logistical concept is to load and unload large vessels on a reduced area of land with minimal impact on the inland public traffic system and the environment. [3]

In addition, the EMT concept developed by Noell Crane Systems is targeted on maximizing port productivity by directly transhipping boxes from vessel to trains v.v. at the quay.

Noell's solution (Figure 2) features a combination of improved semi-automated ship-to-shore cranes (STS), semi-automated cantilevered rail-mounted gantry cranes (RMG) and rail-mounted automated guided vehicles (AGV) based on linear motor technology (LMTT).

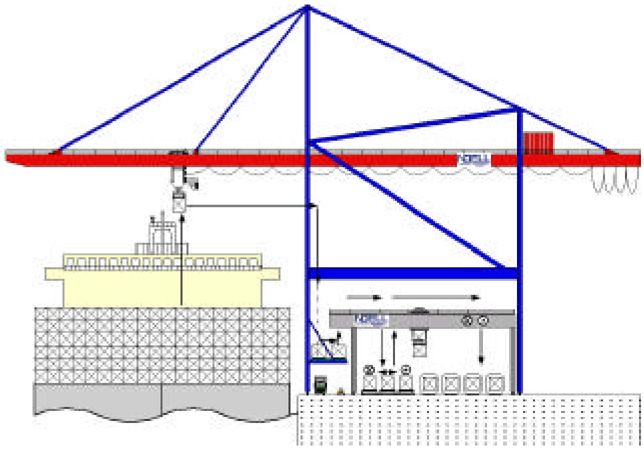

Fig. 2: "Efficient Marine Terminal" – Direct handling of containers between vessel and trains

Drawing on the experience of the Noell ultra modern quay cranes with lashing platform in Hamburg (HHLA), the Noell test site for gantry crane automation in Wuerzburg as well as the LMTT pilot installations in Hamburg (Eurokai) and Wuerzburg the original EMT concept is improved by incorporating the following:

- Single trolley ship-to-shore cranes unloading containers to a platform in the quayside portal, where the twist-locks from deck containers can be removed
- A conveyor to move containers from the lashing position on the platform to a second position underneath an RMG cantilever which could be extended to provide additional buffer-place
- RMGs operating under the portal of the ship-to-shore cranes, covering e.g. four rail lanes and three linear motor transfer lanes
- Two extra service lanes under the lashing platform of the STS

The big advantage of Noell's concept is that yard transfer vehicles are not required, saving a great deal of machinery and labour, which, it should be remembered, is not particularly cheap in North America. When serving the vessel, one duty of the RMG would be to take containers from the platforms and place them on the linear motor transfer system or the rail cars on the shortest possible way v.v.. The linear motor lanes would themselves be at least as long as the trains to be served at quayside, and could serve additional RMG loading/ unloading along the trains (second duty) as well as a buffer stack where this is required. The linear motor system would allow boxes being out of sequence, to be held aside and shuffled without interrupting the ship-to-shore import/ export cycle. Five to eight RMGs could service five ship-to-shore cranes between them. [3]

IV. BUNDLING OF RAIL-BOUND CONTAINER FLOWS INLAND - INNOVATIVE HUB TECHNOLOGY

A. "Intermodal Interface Center"

The "Intermodal Interface Center" as proposed by the U.S. consortium operates like a conventional rail terminal, performing either rail transhipment (without using an efficient sorting facility) or RMG / hostler transfer.

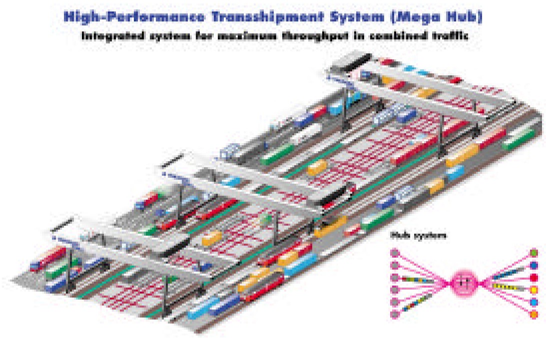

Fig. 3: "Intermodal Interface Center" (MegaHub) – Transhipment instead of shunting

In addition, the IIC concept proposed by Noell Crane Systems is targeted on maximizing node productivity by featuring a combination of semi-automated cantilevered rail-mounted gantry cranes and a sorting facility based on rail-mounted automated guided vehicles driven by linear motor technology. This innovative MegaHub technology as it is known, was elaborated by Noell on behalf of the German Railways for bundling continental container flows [4] and is to be implemented near Hanover / Germany within the next few years (Figure 3).

B. MegaHub [5]

The MegaHub has been developed for the transportation of container numbers that are currently considered to be too small to make it cost effective for direct train carriage. (For benefits to the railway network refer to [8]). Instead, they are carried over turntables, the MegaHubs [6].

Initially all containers are loaded onto the train, including those not scheduled for the train's particular destination. These are then off-loaded once the train has stopped on the turntable and loads from other trains intended for the first train's specific destination are loaded on. The containers have to be loaded in groups according to destination but no shunting is necessary. The actual transfer is undertaken on a surface occupying an area as small as 730m x 80m, at a rate of up to ten ITU (Intermodal Transport Units, either a container or swapbody) a minute between dedicated trains. The storage capacity is a maximum of 270 parking slots but can be enlarged.

Each transfer is carried out using electrically-powered and semi-automated cantilevered yard gantry cranes which span the transfer area and are able to lift to and from road vehicles, railway wagons, pallets on casters and the storage area. The first MegaHub at Lehrte is planned to consist (in its initial state) of three semi-automated gantry cranes and about 12 fully automated shuttle cars controlled by an overall computer system. The transfer by crane is best done while the crane is travelling over very short distances. Long distance travel is carried out by intermediary pallets on casters (shuttle cars), which can move along or across the transfer area (this is on one level only).

The outstanding feature of the MegaHub concept is the modular construction using classic transfer technology. Put another way, if a very high level of performance is not required, fewer gantry cranes can be used. Containers can first be stored flat at the location where, later, the runway for the pallets can be installed. For higher performance requirements it is possible to add extra cranes and to integrate the pallet system.

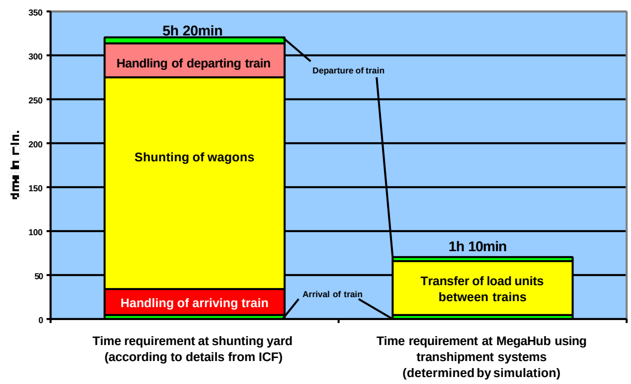

Fig. 4: Minimum time spent by load units in the shunting yard or transhipment yard

In January 2000, Noell presented the results of a recent feasibility study [7] for the MegaHub concept, which formed part of the EC–funded TERMINET project [8] to an expert hearing arranged by the German Social Democratic Party at the new Reichstagsgebäude in Berlin [9]. Noell is focusing on the MegaHub's main advantages: using transhipment to eliminate shunting, increased handling speed and minimized land area and cost per transfer.

For cost and productivity comparisons, recent figures from Metz in France, where most container trains of the ICF Quality Net service are shunted, were used. When shunting was eliminated, the handling speed was increased remarkably (Figure 4). Handling six trains of 40 wagons with 64 ITU on each train takes five hours and 20 minutes using a shunting yard. Using a MegaHub with six gantry cranes and 15 pallet wagons this can be reduced to just one hour and 10 minutes. This enables the number of ITU handled to be increased from 1,120 per day (maximum capacity of the existing shunting yard) to 2,500 (maximum capacity of the MegaHub using 6 gantry cranes and 15 pallet wagons).

The high performance of a MegaHub with up to 10 gantry cranes and up to 45 pallets running together has been proven by simulation in two independent doctoral theses: Dr. Peter Meyer's at the University of Hanover [10] and that of Dr. Knut Alicke at the University of Karlsruhe [11].

The cost savings are equally impressive (Figure 5). In the case of Metz the operational cost per move (visit!) ranged from DM 10.80 (3 shifts, 870,000 visits per year) to DM 15.20 (1 shift, 290,000 visits per year) with minimum personnel required. By comparison, Noell estimates that the cost of handling 700 wagons per day (1.6 ITU per wagon) in the existing shunting yard at Metz in France is DM 40 per ITU.

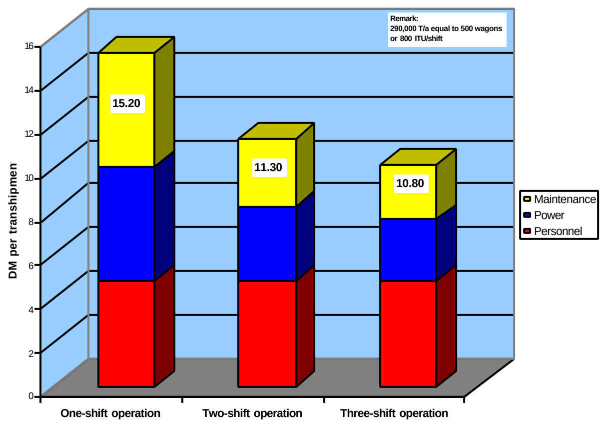

Fig. 5: Case study MegaHub Metz - Operating costs

As far as total costs are concerned, a MegaHub in Lehrte (10 gantry cranes, 45 pallet wagons) able to handle 3,600 wagons carrying 5,760 ITU per day is estimated to require an investment of DM 210 million, of which DM 120 million is for superstructure. The cost of shunting infrastructure to handle the same throughput at the Munich Nord One facility was DM 500 million.

Aside from the impressive cost savings, perhaps the MegaHub's greatest advantage for the future is the minimal amount of land it requires. Taking the Lehrte/Munich Nord example again, the Munich site needs 130 ha on which to handle 3,600 wagons per day, compared with a mere 10 ha for a MegaHub.

V. HIGH CAPACITY BOX MOVER FOR COLLECTION/ DISTRIBUTION ALONG THE TRAINS

Part of the "Efficient Marine Terminal" as well as of the "Intermodal Interface Center" (MegaHub) is a horizontal transport system for the collection / distribution of boxes along the trains featuring linear motor-based transfer technology. Due to heavy obstruction, there would be no efficient container handling possible without such an horizontal transport system when loading / unloading trains by several gantry cranes using the same track.

A. *Linear motor-based transfer technology (LMTT)*

Generally the fully automated horizontal transport system consists of a system of tracks running parallel and at right angles to one another. Fully Automatic shuttle cars are conducted lengthwise and crosswise along these tracks (Figure 6). What makes the system so attractive for applications in container terminals [9] is the wagon's ability to turn at right angles by moving the wheels by 90° instead of turning the whole wagon.

Fig. 6: LMTT - Pallet wagon – Propelled by electro-magnetic force

The shuttle cars are rail-mounted and bi-directional (straight ahead and sideways). They comprise a base frame and a loading platform that is capable of carrying loads up to 41 tonnes, which may be well increased to 54 tonnes for twin-lift operation. They are also equipped with double wheel sets that can be rotated 90° for the carrying and guiding functions. In addition, permanent magnet strips have been installed for the transmission of the driving power (Figure 7). The units for drive (linear motors) and position detection are integrated into the runway. The control system is stationary.

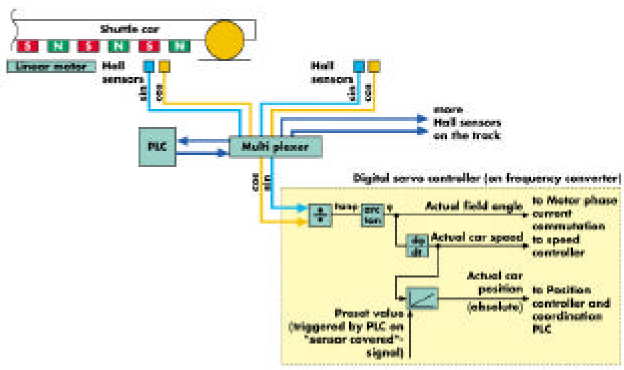

Fig. 7: LMTT - Position detection system

The runway consists of ordinary UIC 60 rails, mounted on steel twin sleepers. To make it possible to turn the wheel sets (of the shuttle cars), a circular steel surface with transverse guides has been fitted at the crossing points, i.e. the intersections of the longitudinal and transverse travelling rails (Figure 6).

A major advantage is that the chassis does not need an engine, brakes, gears, a PLC or sensors. The shuttle cars are driven by means of contact-free linear synchronous motors, which are distributed over the unit according to the requirement of driving force. They act on the magnets located on the underside of the shuttle cars. It is possible to set a variable speed by means of a mobile electromagnetic field, generated using a frequency converter. A contact-free actual position detection system is integrated into the runway and responds to the individual magnets located on the shuttle cars. This enables the absolute position of the shuttle car to be determined and supplies the input values required to ensure that the linear drives are supplied with power and switched over in the correct order. The shuttle cars move at 3 m/s with an acceleration of 0.3 m/s² and can be positioned with an accuracy of +/- 3 mm. With so few moving parts, maintenance costs are kept to an absolute minimum and no fossil fuel is required. [13]

The linear motor-driven transfer technology was initially developed with funding from the German Ministry of Research, BMB+F [14]. Between 1995 and 1998, test and demonstration plants (on a scale of 1:1) were set up at the Port of Hamburg (Eurokai [15]), at the headquarters of Noell Crane Systems GmbH in Wuerzburg (both in Germany) and on the plant grounds of Noell Crane Systems (China) Ltd. in Xiamen.

B. Simulation of the box mover based on LMTT

Each, EMT (Figure 2) and MegaHub (Figure 8), features two runways for longitudinal travel in parallel to the trains. One runway for each direction, plus one transfer lane between with access from both runways by a “side wards step” of a shuttle car. The transfer lane is also used for parking and loading/unloading of the shuttle cars by the gantry cranes. Each of these box movers is no wider than 13 m and about 700 m long.

Of course it is of high importance to know how many shuttle cars are necessary to fulfil given transport requirements and whether there might be deadlocks or not.

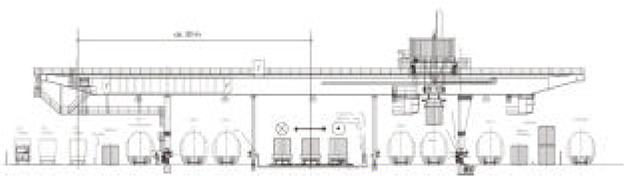

Fig. 8: MegaHub application of box mover

The modelling of the box mover as well as the simulation was done by using a version of SCUSY [ISL, Bremerhaven] which was exclusively upgraded for Noell by adding an LMTT software module. This version of SCUSY enables the programmer to design the layout of the horizontal transport system easily by choosing from a software library of standardized runway modules (uni-/ bi-directional, longitudinal/ transverse, crossings) which may be further specified to a certain extent. It is important to say that the LMTT software module features traffic regulations at crossings as well as distance regulations between vehicles following each other while taking into consideration realistic kinematics and time requirements for positioning etc. of the vehicles.

The simulation (duration = 100 min) was based on the following assumptions:

- Transhipment of boxes between 6 trains, each of them being 700 m long
- Random distribution of boxes between trains
- Layout of the box mover (700 m x 13 m) as described above (Figure 9).
- Access to loading/unloading position by shuttle cars only from one of the two runways possible (no trespassing!)
- Shuttle cars dedicated to selected transport relations
- No optimisation of empty run of shuttle cars
- Geometry and kinematics of the shuttle cars derived from the MegaHub Lehrte project.
- Fixed length of work area per (gantry) crane is 700 m / no. of cranes. (Refer to [10], [11] for variable length of work areas.)
- No obstruction by neighbouring cranes. (Refer to [10] for obstruction by neighbouring cranes)
- Geometry and kinematics of the gantry cranes derived from the MegaHub Lehrte project.
- Transport requirement = no. of visits per time unit (= boxes/100 min)
- Differentiation between direct and indirect (via box mover) transhipments
- No. of visits = no of direct + no. of indirect transhipments
- No of direct transhipments = 38 = approx. no. of visits / no. of cranes (Refer to [11].)
- No. of cranes and no. of shuttle cars are subject to change.

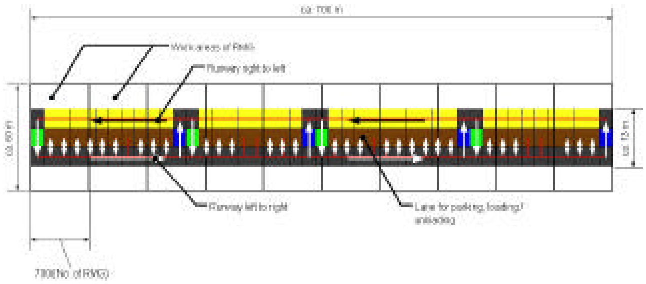

Fig. 9: Layout of box mover based on LMTT (MegaHub)

The outcome of the simulations is condensed in Figure 10, which shows the relation between transport requirements (boxes to be transhipped between trains within 100 min) and no. of cranes / shuttle cars to do the job.

Based on the assumptions above it is possible to do a maximum of approx. 360 (= 6 x 60) direct and indirect transhipments between 6 trains by operating 10 gantry cranes which means to completely interchange boxes between trains having a capacity of 60 boxes each within 100 min.

By doing maximum performance 360 (1 – 1/10) = 324 boxes have to be moved by 40 shuttle cars. As a rule it can be said that 4 shuttle cars are needed to serve one gantry crane in such a MegaHub application.

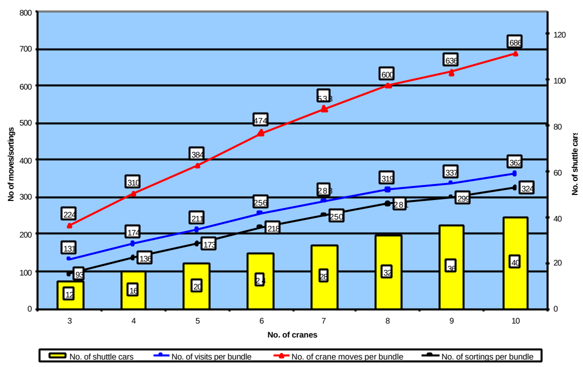

Fig. 10: Outcome of SCUSY simulation (100 min)

VI. References

[1] Kreutzberger, E. (1999):
Innovative networks and new-generation terminals for intermodal transport – Improving the cost-quality ratio by bundling flows. The Nederlands TRAIL Research School, TRAIL 5th PhD Year Congress 1999. Delft.

[2] Vickerman, M. J. (1999):
Agile Port Concept. http://www.transystems.com .

[3] Avery, Paul (2000):
Inventing a way out of trouble. – Cargo Systems Vol 27 No 8. IIR Publications Ltd., London.

[4] Franke, K.-P. (1997):
Lehrte/Hannover - Mega-Drehscheibe für den Kombinierten Verkehr (MegaHub for intermodal transport). Presentation for the symposium Europe towards Intermodal Transport of the European Intermodal Association (EIA). Vienna.

[5] Avery, P. (2000):
MegaHub gains momentum. – Cargo Systems, April 2000. IIR Publications Ltd, London.

[6] Noell Crane Systems GmbH (1999):
Intermodal Transport Systems of the Future – Video.

[7] TERMINET-Consortium (2000):
Performance analyses – 5 new-generation terminal case studies [Deliverable D10]. Report for DG-VII of the European Commission.

[8] TERMINET – Consortium (2000):
Final report for publication. Report for DG – VII of the European Commission.

[9] Franke, K.-P. (2000):
Innovative Mega-Drehscheibe für den Kombinierten Verkehr (Innovative MegaHub for intermodal transport). Presentation as a part of the expert hearing „Zukunftsperspektiven des Kombinierten Verkehrs – Technische Innovationen und Systeme“ (Future prospects of intermodal transport – technical innovations and systems) for members of the SPD fraction in the Bundestag. Berlin, January 2000.

[10] Meyer, P. (1999):
Entwicklung eines Simulationsprogramms für Umschlagterminals des Kombinierten Verkehrs (Development of a software tool for the simulation of transhipment terminals for intermodal traffic). Doctoral thesis approved by the University of Hanover. Shaker Verlag, Aachen.

[11] Alicke, K. (1999):
Modellierung und Optimierung von mehrstufigen Umschlagsystemen (Modeling and optimization of multi-stage transshipment systems). Doctoral thesis approved by the University of Karlsruhe. Scientific reports of the Institut für Fördertechnik und Logistiksysteme of the University of Karlsruhe, Karlsruhe.

[12] N.N. (2000):
Noch preiswerter im Umschlag? – HANSA International Maritime Journal, Feb. 2000. Schiffahrts-Verlag “Hansa” C. Schroedter & Co., Hamburg

[13] Bauer, R. (1998):
Innovative Linear Motor-Based Transfer Technology Allows Intelligent Container Handling. Presentation for the "EURNAV 98" conference. Hanover.

[14] Consortium (1997):
Container-Transportsysteme der Zukunft (Container transport systems of the future). R&D project on behalf of the German Federal Ministery of Education, Science, Research and Technology BMB+F.

[15] Wölper, A., Huth, E. (1997): Introducing linear motor-based transfer technology to a container handling environment.- Barcelona: Terminal Operations Conference 1997.